

Overview

I believe that effective science curriculum and instruction can be guided by multiple theories of learning. In my opinion, the choice of one theory over another in the design of learning should be guided by the purpose of the learning and the particular challenges students face when learning in different domains. If, for example, learners are engaging with phenomena where there are strong pre-conceptions, such as the physics of falling objects, then instruction designed on the basis of conceptual change theory, or Piagetian constructivism, might be warranted. However, if the objective is to help students construct meaning from a text, then literacy-based instruction guided by socio-constructivist ideas may be more appropriate. Finally, if the purpose of learning is to engage students in practices such as the analysis and interpretation of data or scientific argumentation, then a situated perspective on learning might be the best way to help students become competent users of these scientific practices. My pluralistic stance on science teaching and learning is founded upon the assumption that, at present, there is no universal theory of how people learn, or for that matter, how people behave in learning situations because teaching and learning are complex cultural endeavors. That does not mean that all theories of learning are equally valid or that there is no basic knowledge about how to design effective curriculum and instruction. Instead, it means that the task of the expert is to determine which theories of learning are applicable in which learning situations. In this teaching statement, I explain my philosophy on effective curriculum and instruction in K-16 science teaching and also my framework for teacher education. Then I provide an example of how I use different learning theories and instructional tools to design science teacher education courses aligned with my philosophy on K-16 science teaching.

Science teaching. Effective curriculum and instruction in science requires instructional coherence, assessment of student thinking, attending to learners' prior knowledge and experiences to help them construct new knowledge, and accounting for motivation and student identity. Regarding coherence, effective science teaching involves the design of objective driven lesson plans through backwards planning frameworks. These lessons should form an overarching science narrative that targets an essential question that is meaningful to students and based in the core ideas of a discipline. Ideally, the big ideas in such lessons should be taught in a way that makes them relevant to students' identities to activate their motivation to learn. Motivation can be accomplished in many different ways, but I try to establish motivation by anchoring learning in a phenomenon or problem that is relevant to student identity. Thus, a core aspect of teaching is that teachers know their students. Regarding assessment, science instruction should begin with a pre-assessment of the learner's prior knowledge because new knowledge is built upon, contrasted with, and constructed upon the learner's previous knowledge. During the course of instruction, teaching should engage students in participation structures that allow for academically productive talk about the relevant science concepts. Teachers should guide future instruction by learning what their students think via embedded formative assessments (e.g., clicker questions). At the end of instructional units, students should have an opportunity to demonstrate their understandings through a performance assessment that requires them to apply newly constructed knowledge in a novel circumstance. Each of these phases of teaching should provide students with feedback on their learning through the use of rubrics and through feedback framed by a "growth-mindset" perspective that values effort, repeated practice, and perseverance. At the K-12 level, instruction should be aligned with NGSS and at the undergraduate level with Vision and Change.

Science teacher education. As a science teacher educator, I design and teach courses modeled on my science curriculum and instruction principles. The big ideas that organize my teacher education curriculum are the goals of science education (e.g. democratic, cultural, utilitarian, or economic imperatives for teaching science), assessment of student thinking, instructional coherence in curriculum design, instructional tools based in learning theory, disciplinary literacy, and equity and social justice in science education. The tools that I use to support the learning of these ideas are video analysis of teaching cases, reading and discussing instructional dilemmas in teaching cases, curriculum and assessment critique, and reflecting on personal science learning. Using these tools, I provide opportunities for teaching candidates to build new knowledge through argumentation, discussion, and debate (i.e., academically productive talk).

An example. I would begin by asking teachers to design, implement, and analyze responses to pre-assessments so they can learn about the knowledge of their students in a domain that is relevant to their student teaching. On the basis of that learning, I would organize teachers in groups to write objective driven lessons

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aligned with 3-dimensional NGSS instruction and/or the Vision and Change standards for Undergraduate Biology Education. I would provide teachers with scaffolds to help them design lessons that build upon students' prior knowledge and experiences. I would further support this learning with video-into-practice professional development materials. Additionally, I would support new teachers by having them read and debate instructional dilemmas related to their teaching using teaching cases, such as WestEd's *Making Sense of Science* curriculum. Then, as a class, we would brainstorm ways to anchor the learning in the developing lessons with a phenomenon that is motivational. Finally, we would critique each lesson to improve it and assess how it embodies principles of learning theory.

As argued in the introduction, many important theories exist. When I introduce new teachers to a conceptual change model of learning, it is to help them understand how to design instruction when there are strong pre-conceptions about a phenomenon. During those lessons, it is also important to introduce critiques and revisions of conceptual change theory (e.g., Disessa's KIP theory) and to actively mitigate against deficit theories of 'student misconceptions'. At the same time, the construction of new knowledge is shaped by language, identity, and a sense of social-belonging in the culture of the science classroom. The learning of science is a form of situated cognition (Brown, Collins & Duguid, 1989) where the cognitive work of each learner is situated in the cultural and linguistic setting of the science classroom. Therefore, effective science instruction introduces students to the conceptual tools of science through the language of science. It educates students about how scientists write scientific texts, how they read scientific texts, and how they argue about scientific ideas. Thus, I believe that good science teacher education must introduce educators to disciplinary literacy. This means helping new educators move away from instruction based on a transmission model of education that is defined by an initiation-response-evaluation model. It means moving teachers toward a model of instruction where students can talk about, write about, and represent their knowledge. Consequently, as a science teacher educator, I regularly teach and model instruction on: (i) academically-productive talk; (ii) the difficulties of reading science texts and how to teach reading in science to promote argumentation and debate (see: <http://serpmedia.org/rtl/index.html>); (iii) how to write to learn science by engaging teachers in various writing scaffolds, such as Brian Hand's science writing heuristic; and (iv) how to support the writing of scientific arguments and explanations with drawing, reading and talking scaffolds.

In each lesson, I always create a time for a science learning activity. I might ask teachers to collect, analyze and/or interpret data from their own study, an available data set, or a computer simulation (e.g. <https://phet.colorado.edu/>). Teachers would then be asked to construct a model that explains their data. Then, they would be asked to argue with one another to create a consensus model that best explains all the data. As a group, they would critique each other's arguments by questioning the methods, evidence, or reasons used by each research group during a gallery walk activity. After, we would reflect upon the lesson to understand how learning was designed to engage them in scientific practices such as argumentation or using models. At this point, I would assign readings on Cynthia Passmore's model-based reasoning tool, Jon Shemwell's work on helping learners to abstract models through analogical induction, and work on argumentation by Jonathan Osborne, Kate McNeill, and Victor Sampson.

As teaching candidates learn how to scaffold these types of instruction, I would begin to introduce ideas of equity and social justice in science education. First and foremost, science teachers need to develop an awareness of how hidden cultural biases affect the teaching of science. I typically introduce this idea by having teachers watch videos (e.g. tools for ambitious science teaching [videos](#)) where science teachers show a clear bias of calling on boys in classroom discussions. Afterwards, I would assign readings that deal with equity in science education, such as work by Okhee Lee, Glen Aikenhead, Julie Bianchini, Bryan Brown, Megan Bang, Marcia Linn, and my own work when it is relevant. Then, we would use these ideas to analyze and critique the lessons we developed earlier in the semester to make them more equitable, and/or culturally sustaining. We would also critique lessons from my intervention studies and try to improve them to make them more culturally relevant and inclusive in the classroom context where a candidate's student teaching is occurring.

At the end of this learning, teachers would have developed a coherent mini-unit. Students would be given a rubric for their mini-unit that includes dimensions on equity, learning theory and instructional scaffolds, assessment, and the relevant instructional standards (e.g., NGSS or Vision and Change). After scoring their own unit and critiquing the work of others, they would revise their work and hand in the mini-unit as the summative assessment for the course.